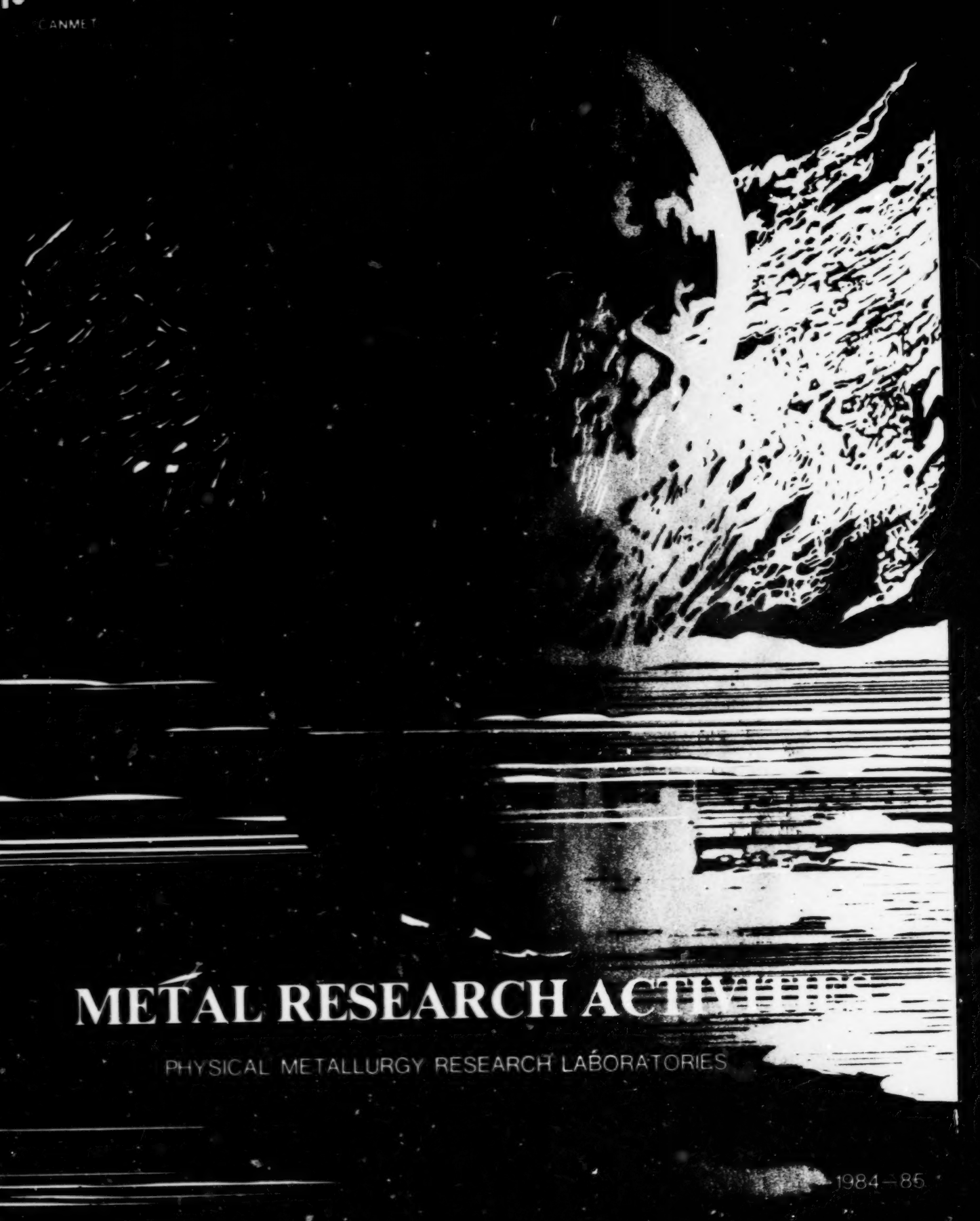
CANMET



METAL RESEARCH ACTIVITIES

PHYSICAL METALLURGY RESEARCH LABORATORIES

1984–85

85-0265/

Cover Design by Susan Risk

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

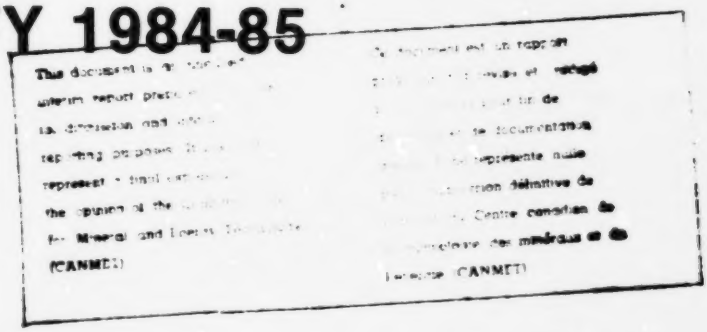
PHYSICAL METALLURGY RESEARCH LABORATORIES

568 Booth Street, Ottawa, K1A 0G1

CANMET

ENERGY, MINES AND RESOURCES CANADA

METAL RESEARCH ACTIVITIES FY 1984-85



Compiled by
C. Dixon, Information Officer
TEL (613) 995-4807

MICROMEDIA
OCT 26

66 pp

MRP/ERP/PMRL 84-32(IR)

APRIL 1984

FOREWORD

This brochure is an outline of the planned R & D to be undertaken by the staff of the Physical Metallurgy Research Laboratories (PMRL), CANMET, Department of Energy, Mines and Resources during FY 1984/85. The purpose of this document is to make PMRL's research plans known, and to invite responses to it from the private and public sectors alike.

It is estimated that approximately 140 person years of in-house effort will be called for to implement this program. In addition, over 20 per cent of the budget allocated to PMRL will be devoted to contracting appropriate aspects of the program out to the private sector.

To facilitate early publication, project texts have been taken directly from working papers.

W.H. Erickson
Director, Physical Metallurgy
Research Laboratories
Tel: (613) 593-4929

AVANT-PROPOS

Cette publication donne un aperçu des activités de recherche et de développement que les Laboratoires de recherche en métallurgie physique (LRMP) CANMET, Énergie, Mines et Ressources Canada, prévoient entreprendre durant l'année financière 1984/85. Par la publication de ce rapport, les LRMP désirent faire connaître leurs perspectives de recherche et recevoir les commentaires des secteurs privés et public.

On prévoit qu'environ 140 années-personnes seront consacrées à la mise en oeuvre interne de ce programme. En outre, plus de 20 pour cent du budget des LRMP sera affecté au secteur privé pour la mise en oeuvre de certains aspects du programme.

Par souci d'économie du temps, les textes du projet ont été puisés directement des ébauches.

W.H. Erickson
Directeur, Laboratories de
recherche en métallurgie
physique
Tel: (613) 593-4929

TABLE OF CONTENTS

	Page
FOREWORD	i
AVANT-PROPOS	ii
ALLOY DEVELOPMENT	
Development of Advanced Methods and Materials	3
Heat Treated Rail	4
Microstructure and Properties of Engineering Alloys	5
CORROSION	
Corrosion Mechanisms	9
Materials for Coal Handling and Utilization	10
Materials for High-temperature Energy Conversion Processes	11
Tar Sands Processing	12
FOUNDRY TECHNOLOGY	
Degradable Sand and Core Binders	15
Electroslag Casting	16
Exploratory Foundry Research	17
Permanent Mould Casting	18
Mobile Foundry Laboratory	19
Processing of Ultra-clean Steels	20
Zinc-base Foundry Alloys	21
FRACTURE MECHANICS	
Plastic Flow, Fracture and Stress Analysis	25
CANMET Portable X-ray Stress Diffractometer	26
MARINE MATERIALS	
Cost Shared Industrial Program on Steels for Offshore Applications	29
Marine Materials	30
Naval Materials	31
Steels for Offshore Structures	32
Structure Integrity Monitoring of Offshore Structures	33

Table of Contents (Cont'd)

	Page
METAL FORMING	
Formability and Processing of Sheet Steels	37
Near Net Shape Forging	38
Rolling Mill Processing Technology	39
PIPELINES	
Oil and Gas Pipelines	43
Oil Country Tublar Goods	45
WELDING	
Effect of Nitrogen on Weld Notch Toughness	49
Pressure Vessels	50
Repair and Reclamation by Welding	51
Thermal/Mechanical Simulation of Metallurgical Processes	52
Welding Process Development	53
Welding Mechanics	54
OTHER	
Certification of NDT Personnel	57
Cost Recovery and Technology Transfer in Metals Processing	58
Cost Recovery and Technology Transfer in Materials Development	59
NDT Technology Development	60

ALLOY DEVELOPMENT

DEVELOPMENT OF ADVANCED METHODS AND MATERIALS

Project Leader: R. Packwood
Telephone: (613) 593-7086

Objective

To develop new methods and materials in advanced technologies to support or stimulate industry, or to maintain in-house scientific, particularly analytical, capability state-of-the-art.

Background

This project is a selected grouping of innovative and developmental activities in advanced technologies.

In PY 1984-85, there are the following highlights:

i) Rapid solidification (RST) is a new technology which has attracted world wide interest and is being actively pursued in Japan, the US and Europe. RST holds the promise of leading to materials with a number of new or enhanced properties or combination of properties. A number of contacts have been made, industrial and otherwise, and a combination of contract funding and in-house research will be directed towards stimulating industrial activity in Canada in this important emerging technology.

ii) Microelectronic devices are becoming so small that the traditional techniques used to study their structures are no longer adequate. With its combination of materials expertise and clutch of state-of-the-art electron beam instruments, PMRL is in a unique position to provide support to local industry in analytical microscopy.

iii) The work to develop new techniques in analytical microscopy to meet new challenges posed by the emerging wave of microelectronic devices is perhaps a special example of a continuing activity, particularly in surface and micro-analysis, to maintain the PMRL capability state-of-the-art.

Planned Activity FY 84/85

- Develop new analytical methods for SEM and CAMECA microprobe.
- Develop specimen preparation techniques for the TEM.
- Determine O_2, N_2 and H_2 in steels.
- Develop in-house techniques for examining semiconductor materials in the TEM/STEM.
- Initiate a program of research on RST.
- Organize a seminar on "RST in Canada".

HEAT TREATED RAIL

Project Leader: D.M. Fegredo
Telephone: (613) 593-7104

Objective

To develop a rail steel with wear resistance equal or superior to the best premium rails currently available.

Background

Current premium rails range in hardness from Rc 34 to Rc 39 and early accelerated-cooling work in PMRL defined conditions that produced pearlitic microstructures of hardness Rc 38 in lean-alloy eutectoid steels. Results from a collaborative investigation with Dr. J. Kalousek of NRC, Vancouver on the effects of microstructure and hardness on wear resistance show that little benefit occurs by increasing the hardness beyond Rc 38-40. Metallographic work indicates that cracks at worn surfaces are predominantly associated with MnS inclusions. The results to date lead to the tentative conclusion that an accelerated-cooled lean-alloy rail with low sulphur, a pearlitic microstructure and a hardness of Rc 38-40 should have optimum wear properties. Experiments will be carried out to demonstrate this as well as to complete the present microstructure-hardness-wear resistance correlation studies and evaluate the effects of volume fraction and type of inclusion on wear resistance.

Planned Activity FY 84/85

- Monitor a contract on TEM study of the effect of simulated rail loading on selected rail steels.
- Determine resistance to wear of certain experimental and commercial premium rail steels.
- Investigate the mechanical properties and microstructure produced by spray cooling a lean-alloy rail steel (0.8% Cr).
- Determine the effect of inclusions on the wear and fatigue properties of experimental premium rail steels.
- Establish a technique, with the Gleeble machine and quench-deformation dilatometer to simulate rail steel flash-butt welds.
- Determine controlled-cooling routes that reduce excess hydrogen to safe levels in SYSCO Cr-Si-V premium rails.

MICROSTRUCTURE AND PROPERTIES OF ENGINEERING MATERIALS

Project Leader: J.D. Boyd
Telephone: (613) 593-7129

Objective

To characterize the microstructure of engineering alloys and materials, and to determine microstructure - property relationships.

Background

Controlling microstructure to achieve required combinations of properties is fundamental to the manufacture of engineering materials. This project explores the basic microstructure-property relationships in a number of alloy systems. The use of state-of-the-art electron microscopy, micro nalysis and image analysis techniques is emphasized.

Planned Activity FY 84/85

- Determine transformation kinetics and microstructure of simulated HAZ's of Ti-Nb steels.
- Determine the effects of deformation on austenite to ferrite transformation behaviour.
- Determine the effects of boron, carbon and nitrogen on the transformation kinetics and microstructure of ultra low carbon bainite steels.
- Determine precipitation characteristics in Cr-V eutectoid steels.
- Determine microstructural effects on delamination fractures in microalloy steels.
- Determine microstructural effects on HAZ fracture behaviour.
- Hold conference on "Effects of Inclusions and Residual Elements on the Fabrication and Service Behaviour of Steels".
- Determine microstructure and grain-refining mechanisms in Ci-Ni-Sn spinodal alloys.
- Characterize microstructure and grain-boundary segregation in Al-Li alloys.
- Develop techniques of automatic image analysis with optical microscopy, SEM and TEM/STEM.
- Determine effects of inclusion type and distribution on the machinability of commercial heats of free-machining steels.

CORROSION

CORROSION MECHANISMS

Project Leader: J.B. Gilmour
Telephone: (613) 593-4527

Objective

To contribute to the understanding of the mechanisms involved in the corrosion and erosion-corrosion of metals.

Background

The nature of the work in this project is two-fold. First, most of it is carried out in support of current applied corrosion research and is aimed at shedding light on basic mechanisms responsible for general corrosion, stress corrosion cracking and corrosion-erosion. In this way it is hoped to invest the applied research in other projects with greater insight and understanding.

Second, the inclusion in FY 1984-85 of a study carried out on corrosion in a municipal water distribution system in Calgary is a departure in that it is itself a specific instance of applied research.

Planned Activity FY 84/85

- Investigate the efficiency of oxy-anions in inhibiting the corrosion of steels in coal-water slurries.
- Continue to disseminate information on municipal water pipe corrosion.

MATERIALS FOR COAL HANDLING AND UTILIZATION

Project Leader: J.B. Gilmour
Telephone: (613) 593-4527

Objective

To establish a data base on materials properties and performance in coal combustion and conversion technologies, specifically:

to complete the evaluation of alloys in the EMR-Nova Scotia Power Corporation fluidized-bed coal combustion project at Point Tupper N.S.; and

establish alloy selection data for coal utilization technologies.

Background

The long-term performance and cost effectiveness of materials used for boiler tubes and the like has been identified as a major consideration in coal-fired fluidized-bed combustors for power generation. Under EMR's Oil Substitution Policy, a series of ten tests with a maximum exposure time of 10 000 hours of candidate materials is being conducted in Nova Scotia by NSPC, PMRL is evaluating the materials tested.

The performance of key materials used in coal gasification and liquefaction processes are also assessed in this project.

Planned Activity FY 84/85

- To evaluate the performance of alloys used for heat transfer tubes in a series of 10 x 1000 hour tests in the $1m^2$ atmospheric pressure fluidized bed combustor at Point Tupper N.S.

MATERIALS FOR HIGH-TEMPERATURE ENERGY CONVERSION PROCESS

Project Leader: J.B. Gilmour
Telephone: (613) 593-4527

Objective

To solve a selected number of materials' problems identified as potential restraints to the development of large-scale energy conversion processes, specifically:

to characterize the creep-rupture properties of materials used in coal-conversion systems; and

to characterize the behaviour of materials used in high-temperature corrosive/erosive environments.

Background

In the development of advanced fossil energy conversion and utilization processes, serviceability of materials in high-temperature, high-pressure corrosion/erosion environments is identified as one of the most important restraints.

The purpose of the work in this project - a substantial contract program, with in-house support work - is to contribute to the development of the materials required and to establish base-line data on materials' performance.

Planned Activity FY 84/85

- Characterize the performance of Fe-Cr alloys in simulated coal combustion.
- Study the high temperature oxidation of low alloy steels.
- Monitor a contract to determine effect of the operating environment in coal conversion processes on the mechanical properties of selected alloys.
- Monitor a contract to investigate the creep rupture properties of alloys in simulated FBC environments.
- Monitor a contract to investigate the use of ion implantation and ion mixing to produce oxidation resistant alloys.
- Monitor a contract to identify the mechanism of sulphur transport in Cr_2O_3 and provide the solubility/diffusion data required for predicting alloy corrosion behaviour.

TAR SANDS PROCESSING

Project Leader: J.B. Gilmour
Telephone: (613) 593-4527

Objective

To study the corrosion-erosion behaviour of materials used in tar sands processing and in-situ heavy oil recovery.

Background

Tar sands processing and in-situ recovery of heavy oil leads to excessive wear of materials exposed to the extremely severe corrosive-erosive conditions that the processes entail. Proper choice of materials can prevent frequent breakdowns and minimize the overall cost of operation. In this work, the ability of various alloy steels to withstand the wear of tar sands tailings will be characterized, and the materials problems that arise in high temperature in-situ recovery processes will be studied by experiments that simulate operating conditions.

Planned Activity FY 84/85

- Evaluate model of corrosion-erosion in abrasive slurries.
- Evaluate the dependence of corrosion and erosion rates on test velocity and experimental method.
- Determine the individual contributions of corrosion and erosion to the total weight loss in corrosive and non-corrosive slurries.
- Determine if there is any synergism between corrosion and erosion.
- Examine the applicability of the test method to testing at (125°-250°C).

FOUNDRY TECHNOLOGY

DEGRADABLE SAND AND CORE BINDERS

Project Leader: M.K. Buhr
Telephone: (613) 593-7148

Objective

To develop a family of non-petroleum-base, environmentally-acceptable, moulding and core sand binders suitable for ferrous and non-ferrous casting production.

Background

Existing moulding and core sand 'no-bake' binders are either made from organic compounds based on petroleum derivatives or inorganic compounds based on sodium silicate. The petroleum-base compounds release unpleasant and sometimes toxic vapors, and are rapidly increasing in cost. Inorganic binders are difficult to shake out after casting and are also difficult to reclaim after use.

An improved family of moulding and core sand binders is required which have the desirable features of both systems without having any of their undesirable characteristics.

Two binder systems were developed: the Sorel cement binder system which was rejected because it gave off HCL vapours during casting and a non-petroleum base system which is currently under development.

Research to identify other binder systems is continuing. Key characteristics that are being used in the selection process are:
(1) cost, (2) binder strength including time and humidity dependence, (3) binder strength after casting, (4) reclaimability, (5) health factors including odour, toxicity, etc.

Planned Activity FY 84/85

- Study the effect of inorganic halide additives to the moulding mixes.
- Study the possibility of rapid hardening of moulded pieces by ammonia gas.
- Study the feasibility of incorporating zirconyl chloride (in solution) into preparations for coating styrofoam patterns.

ELECTROSLAG CASTING

Project Leader: R.K. Buhr
Telephone: (613) 593-7148

Objective

To design, construct and operate an electroslag casting apparatus to produce thin-wall cylindrical castings to specific compositions.

Background

CANMET's research and development on metal casting processes is focused on improved recoveries and casting quality, near net shape, reduced environmental and health and safety problems and technology transfer. Electroslag casting, although limited in applications, appears to offer significant benefits in these areas. At present no commercial facility for electroslag casting exists in Canada.

In view of CANMET's strong background in metal casting research and its long and good relationship with the Canadian foundry industry, DND has chosen to provide partial funding for CANMET to undertake the work of extending electroslag casting research to lighter sections and to demonstrate electroslag casting to Canadian industry.

Planned Activity FY 84/85

- Establish the operating parameters needed to produce thin-wall cylindrical castings by the electroslag casting process.
- Investigate the extent to which the base composition of electroslag castings can be altered by additions to the molten metal pool.
- Establish the largest diameter rod that can be cast and still be used as an electrode for thin-wall casting production.

EXPLORATORY FOUNDRY RESEARCH

Project Leader: R.K. Buhr
Telephone: (613) 593-7148

Objective

To perform exploratory and basic research on new ideas in metal casting.

To determine specific dynamic thoughness properties of selected ferrous and non-ferrous cast alloys.

Background

The continuing objective of the foundry industry is to produce better quality castings with increased process yields, decreased energy consumption per unit of finished casting with decreased pollution and health and safety problems. Pursuit of this goal requires not only the development of new and improved technological processes but also increased understanding of the phenomena basic to metal casting processes.

As the national centre for foundry research, CANMET carries out research on new processes as well as basic and applied research on metal casting. The aim of this core project is to perform preliminary research as an essential step in the development of long-term projects.

Planned Activity FY 84/85

In the area of suspension casting:

- Study the feasibility of casting molten metal within which solid particles are suspended.
- Monitor a contract to establish base-line data on the dynamic toughness of two common grades (LCC and LC4, ASM 352) of cast steel designed for low-temperature service.

PERMANENT MOULD CASTING

Project Leader: R.K. Buhr
Telephone: (613) 593-7148

Objective

To develop the technology to produce grey and ductile iron castings in permanent moulds by gravity pouring.

To design, construct and test a new casting process utilizing low pressure, evaporative foam patterns and vacuum to produce castings from the higher melting point alloys.

Background

About 90% of all aluminum castings produced in Canada are made in permanent moulds of one form or another, viz. gravity, low pressure or high pressure casting. Some grey and ductile iron castings are also being produced in gravity permanent moulds. The increased cost of sand, environmental problems, closer dimensional tolerance requirements and improved surface finish are reasons why the permanent mould casting offers promise. The significant increase in yield in low pressure casting is an additional reason for this process.

A major problem associated with the production of higher melting point alloys, especially in low pressure casting, is die life. In order to obtain reasonable life, expensive die materials and machining operations are required. To overcome this, a technique has been proposed by which a disposable mould can be used in a low pressure casting process.

Planned Activity FY 84/85

- Monitor a contract to refine existing computer programs to fit PMRL data; begin work on effect of pour time and convection in the liquid metal.
- Examine structures and soundness in gravity-cast permanent mould iron castings as influenced by pour temp., mould temp., inoculation practice, mould opening time, mould design, etc.
- Develop a test for thermal fatique in candidate mould materials.
- Design a suitable flask for intake manifold production.
- Design a low pressure disposable mould casting for high melting point alloys.

MOBILE FOUNDRY LABORATORY

Project Leader: R.K. Buhr
Telephone: (613) 593-7148

Objective

With the CANMET Mobile Foundry Laboratory visit a wide selection of Canadian foundries to analyze alloys produced, characterize sand and the microstructures and properties of the castings, and, by the use of specially designed computer software, suggest remedial actions to improve casting productivity and quality.

Background

The Canadian foundry industry is a fragmented and diverse industry. Generally, the companies in this mature industry have very limited funds available for research and development and technological training of their staff.

The recent, rapid developments in microcomputer technology have resulted in the realization that technology transfer can be greatly enhanced by software specifically created for modelling and controlling foundry processes. Current work on the iron melting project provides an outlook on the potential of this method of technology transfer.

To extend the methodology of the iron melting technology project to all aspects of the foundry industry, a mobile foundry laboratory has been equipped with foundry control equipment and a microcomputer to demonstrate CANMET-developed foundry software. Visits will be made to selected foundries throughout Canada to demonstrate current foundry process equipment and to show how the computer software can be used to improve productivity and quality.

Planned Activity FY 84/85

- Visit Canadian foundries to demonstrate state-of-the-art equipment and identify opportunities for improving techniques.
- Compare mechanical properties of low alloy cast steel made by ladle desulphurization and by AOD process.
- Evaluate sand properties in foundries visited.
- Determine best techniques to permit small foundries to produce ductile iron.
- Monitor contract on the recovery of oxidizable elements in the cupola.

PROCESSING OF ULTRA CLEAN STEELS

Project Leader: A.F. Crawley
Telephone: (613) 593-7136

Objective

To produce ultra clean steels and ultra low carbon steels by developing the facilities and techniques for secondary refining of steels; to establish an on-line accelerated cooling system for the CANMET hot rolling mill to process these steels; and to develop co-operative programs with the Canadian steel industry to evaluate the relative significance of different levels of residuals.

Background:

Experimentation has established the benefits of low residual elements in steel for improved fracture toughness and sulphide stress corrosion cracking in plate and improved ductility in plate, strip and sneet. The benefits of low residuals and low carbon concentrations on weldability are also well known. With the advent of modern instrumentation/ sensor technology and computer controlled processing, the everyday production of these high quality steels has become a critical feature of international competitiveness in the steel industry. Acquiring the plant facilities to produce these steels represents a significant capital burden to the Canadian steel industry. The marginal cost of successive reductions in residual levels becomes increasingly disproportionate. Because of a lack of conclusive data on the relationship between steel cleanliness and properties, there is a need for pilot scale facilities in Canada to produce experimental quantities of steels for joint government-industry-university evaluation.

Planned Activity FY 84/85

- Develop methods to access the cleanliness of cast and wrought steel by characterization of inclusions and setting standards.
- Establish operating procedures for a new vacuum induction unit.
- Develop procedures to reduce and control the level of residual elements S,O,H.
- Monitor a contract to develop and fabricate an on-line accelerated cooling system for the CANMET rolling mill.

ZINC-BASE FOUNDRY ALLOYS

Project Leader: M. Sahoo
Telephone: (613) 593-7076

Objective

To improve the castability and ductility of a new family of zinc-aluminum foundry alloys.

Background

Canada has 17% of the world's reserves of zinc. Because of the abundance of this resource, there is an industrial interest in developing new uses for zinc. Noranda Research Centre has introduced three zinc-aluminum foundry alloys which, for certain applications, compete effectively with cast iron, aluminum, and copper-base alloys. However, optimum procedures for casting the zinc-base alloys have not been developed and the ductility of the alloys is poor. Thus, this project has been established to provide backup to further industrial development of these alloys that will be carried out by Noranda. Specifically, the work will take two forms. First, the foundry characteristics of zinc-aluminum alloys will be determined and used as guidelines for moulding and casting the alloys. Second, the possibility of improving the ductility of the cast alloys by the addition of small quantities of other elements will be investigated.

Planned Activity FY 84/85

- Investigate gating and risering techniques to improve the soundness of sand castings of zinc-aluminum alloys.
- Characterize the phases present in zinc-aluminum alloys and improve their ductility by minor alloying additions.
- Monitor a contract to determine the mechanism of solidification in Zn-Al alloys.
- Develop expertise in low pressure die casting of Zn-Al alloys.

FRACTURE MECHANICS

PLASTIC FLOW, FRACTURE AND STRESS ANALYSIS

Project Leader: W.R. Tyson
Telephone: (613) 593-7103

Objective

To contribute to the theoretical and experimental analysis of fracture in structural materials, and to improve measurements and analysis of internal stresses.

Background

PMRL/CANMET continues to be called upon to contribute to the development of specifications and standards to regulate the toughness of both engineering materials and structures. Its reputation rests largely on practical knowledge gained in research on materials and investigations of structural failures. However, a knowledge of the nature of plastic flow and fracture in engineering materials and of the manner in which these processes are reflected in conventional toughness tests is a continuing requirement for competence in this work.

This project addresses theoretical and experimental work aimed at improving the understanding of flow and fracture and at developing toughness tests that better reflect real conditions in service. In particular, work is underway to extend elastic/plastic fracture mechanics techniques to a broad range of structural materials as well as to measure residual stresses, which can have important effects on the initiation and propagation of cracks. Residual stresses in weldments are especially important in corrosion fatigue.

Planned Activity FY 84/85

- Develop elastic-plastic fracture toughness test methodology.
- Evaluate the suitability of high-speed drilling techniques for residual stress measurements in steel.
- Develop techniques and methods for instrumental impact testing.
- Apply fracture control and methodology to materials selection and specification.
- Develop correlation between toughness and microstructure.

CANMET PORTABLE X-RAY STRESS DIFFRACTOMETER

Project Leader: D.W.G. White
Telephone: (613) 593-7074

Objective

Develop and complete evaluation of the experimental/engineering model of the CANMET Portable X-Ray Stress Diffractometer in support of the continued development in Canada of a commercial diffractometer which measures stresses non-destructively in the surface of engineering structures in the field.

Background

It is important for many purposes to know what stresses are present in engineering structures. Aircraft, ships, pipelines, and nuclear reactors are some obvious examples of such structures. Load limitation, routine inspection, product acceptance, public safety, design evaluation, retirement from service, need for stress relief, are some of the reasons one would want to know the stresses present in a structure.

Stresses can be determined by two basic methods viz: strain gauges and X-ray diffraction. Although strain gauge methods can be applied in the field, they are time consuming and depend on drilling or otherwise removing material from a structure. X-ray diffraction offers a nondestructive means of determining surface stresses, although until recently, mobile equipment had not heen developed for the purpose. The instrument developed in PMRL/CANMET is error compensating and is designed to measure surface stresses at one spot in a structure or specimen from one reading of about 50 s duration.

Planned Activity FY 84/85

- Evaluate and improve experimental model.

Monitor the following contracts:

- Design and construct a commercial prototype.
- Modify experimental model as required.
- Process patent applications.
- Develop in Canada, a source of charged coupled detectors suitable for the CANMET portable X-ray stress diffractometer.

MARINE MATERIALS

COST SHARED INDUSTRIAL PROGRAM ON STEELS FOR OFFSHORE APPLICATIONS

Project Leader: R. Thomson
Telephone: (613) 593-7075

Objective

To foster the steel and fabrication industries' capability to supply appropriate materials and engineering technology to Arctic and offshore developments.

Background

If Canadian industry is to be in a position to take fullest advantage of the industrial opportunities that offshore oil and gas development presents, the pause in the current exploratory drilling phase should be used to identify potential industrial demands and to take whatever steps are necessary to meet them. It is the purpose of this project to help industry respond to this challenge by sharing the funding (50 per cent) of selected research proposals from Canadian industry.

Planned Activity FY 84/85

- Investigate the heat affected zone toughness in selected steels and examine the effect of weld processes and consumables on weld metal fracture toughness.
- Develop and evaluate an all-position mechanized flux cored arc welding (FCAW) system for on-site fabrication of oil and gas structures.
- Evaluate the potential of the pulsed gas metal arc welding (GMAW) of thick section steels for low temperature applications.

MARINE MATERIALS

Project Leader: R. Thomson
Telephone: (613) 593-7147

Objective

To contribute to the development of the production technology, performance characteristics, and regulatory standards for ship structures for Arctic Marine service.

Background

Canada is on the verge of undertaking major multi-billion dollar ocean engineering and construction programs: icebreaking LNG carriers and tankers will be built to carry Arctic energy commodities to southern markets; the Canadian Coast Guard fleet is to be expanded by the addition of Arctic class icebreakers; the exploration for, and development of, non-Arctic offshore energy resources demands the use of offshore structures in a unique, hostile environment; the Dept. of National Defence is also embarking on a major ship-building program.

To obtain the fullest economic benefits from these large capital programs, some by government, some by private enterprise, Canada must maximize its domestic technical capability to supply appropriate materials and fabrication technology for these projects.

Planned Activity FY 84/85

- Study the weld related corrosion of icebreaking ships.
- Evaluate welding techniques for Arctic ships.
- Develop alloys and processing schedules for improved ship plate.
- Prepare a report comparing CSA grades of plate steels with international specifications for ship plate.
- Prepare a report summarizing the compositions and properties of current commercial propeller alloys.

NAVAL MATERIALS

Project Leader: M. Sahoo
Telephone: (613) 593-7076

Objective

To develop a competence among domestic bronze foundries to produce premium quality bronze castings for marine service.

Background

In the world of acoustical detection and surveillance at sea, the noise contributed by a propeller to the total noise made by a ship under way is "sufficiently large" that it becomes worthwhile to attempt to reduce it. Apart from reducing noise by changing propeller design, the proper selection of a propeller alloy can contribute to noise reduction. One of the better alloys for this purpose is "Sonoston", a manganese-copper alloy containing 54.25 Mn, 37 Cu, 4.25 Al, 3 Fe and 1.5 Ni. The fact that there is little or no experience in the public sector in handling this alloy, nor have there been independent evaluations of the mechanical and other properties of the alloy, make it a relevant matter to address.

The situation affecting the nickel-aluminum and manganese-nickel-aluminum bronzes from which propellers are cast is different. Here, in response to shifts in policy, Canadian ships, particularly ships of the Coast Guard service, are penetrating further into ice-infested waters on extended shipping seasons. As a result, equipment is being tested beyong the limits for which it was originally intended. Ships' hulls are being breeched, propeller shafts bent and propellers broken. Current materials will have to be re-evaluated, alternatives indicated, or remedial action recommend.

Planned Activity FY 84/85

- Determine the microstructure, mechanical properties and damping capacity of samples from high-damping propeller blades received from DREA.
- Identify the cause of low toughness in heavy section castings of Ni-Al, and Mn-Ni-Al bronze propeller alloys, and determine remedial treatment.
- Study the properties of weldments in 25 mm thick HY80 steel plate prepared by the submerged-arc process.
- Monitor a contract to investigate the corrosion fatigue behaviour of Mn-Ni-Al bronze propeller alloys.

STEELS FOR OFFSHORE STRUCTURES

Project Leader: R. Thomson
Telephone: (613) 593-7075

Objective

To generate material property and performance data relevant to the fabrication and operation of fixed and floating platforms, ships and pipelines used in the development of offshore and Arctic energy resources.

Background

The quest for national self-sufficiency in hydro-carbons, particularly oil, may lead to the early development of offshore resources. This prospect calls for the federal government to ensure there is an awareness in the public sector of the role of materials in the construction and service performance of platforms and rigs, submarine pipelines and other special marine requirements. The need for this is two-fold; first, to ensure that regulations concerning materials selection and performance are well conceived i.e., much of the current offshore technology was developed for the North Sea oil and gas deposits and must be further adapted for Canadian conditions and second, to take initiatives and provide support, to ensure that Canadian industry profits to the extent possible from the industrial opportunities that offshore oil development affords.

Planned Activity FY 84/85

- Monitor 5 contracts.
- Evaluate the effects of plate thickness, sea water, cathodic protection and improved weld techniques on the fatigue life of welded T-joints.
- Establish the applicability of the cut-and-section technique for residual stress, determination in welded steel joints for offshore structures.
- Evaluate current available welding consumables for use in offshore and Arctic structures and identify areas where toughness may be improved.

STRUCTURE INTEGRITY MONITORING OF OFFSHORE STRUCTURES

Project Leader: V. Caron

Telephone: (613) 593-7105

Objective

To develop and evaluate sensors and monitoring systems for detecting service induced structural flaws in offshore structures.

Background

Platforms and drill rigs operating in Canada's offshore regions will be subject to extremes in service conditions -- high seas, ice and cold temperatures at Hibernia; very cold temperatures and high ice forces in the Beaufort Sea. Current practice for detecting and monitoring growing cracks in offshore structures in more temperate climates must be evaluated for application in Canada to ensure that our inspection systems and divers who operate them have the most suitable technology available. NDE techniques for remote operation are of particular interest in our harsh environment. CANMET resources will be used to develop appropriate NDT equipment and practices for underwater use.

Planned Activity FY84/85

- Develop an ultrasonic underwater system for inspecting and monitoring defects in offshore structures.
- Monitor a contract to develop and implement a general signal analysis system for NDT based on pattern recognition technology.

METAL FORMING

FORMABILITY AND PROCESSING OF SHEET STEELS

Project Leader: A.F. Crawley
Telephone: (613) 593-7136

Objective

To assist the Canadian metal forming industry to process new types of "narrow specification steels" (continuous annealed, plain carbon, high strength low alloy, and dual phase) by contributing to the understanding of the influence of the metallurgy and processing on ultimate formability.

Background

The sheet metal industry is entering an era of new challenge and competitiveness in an essentially mature market. The automotive industry, the major user of sheet steel, has begun to demand strict quality assurance from its suppliers. Other industries will probably follow suit. Fabricators must, therefore, operate with a better understanding of formability and metal flow in order to meet dimensional tolerances and reduce material wastage through failures. With its expertise in metal processing and characterisation, formability testing and analysis of metal flow behaviour, CANMET is uniquely placed to provide the required knowledge to assist in this transition.

Planned Activity FY 84/85

- Investigate the forming behaviour of AKDQ annealed sheet and also the texture development of AKDQ and microalloyed steel sheet.
- Investigate the influence of dynamic texture development on the forming behaviour of dual phase steels.
- Monitor a contract to determine the influence of frictional and microstructural effects on the formability and press shop performance of galvanized steels.
- Monitor a contract for a technological assessment of the Canadian metal forming industry.

NEAR NET SHAPE FORGING

Project Leader: A.F. Crawley
Telephone: (613) 593-7136

Objective

To develop forging techniques which reduce materials and energy consumption by developing an understanding of the interplay of metal flow and microstructural characteristics in the forging process.

Background

Near net shape (NNS) forging provides the opportunity to effect materials savings by reduction of flash, energy savings by reduction in processing steps and economic advantages by reducing finish machining. Forging may be hot or cold. NNS technology has hitherto been applied to very specialized and expensive materials. Although further development of the technology for these materials is valid, significant benefits are also attainable by applications to more common materials in high production processes.

The technical issues are complex because material flow is inherently non-uniform and influenced by strain rates and microstructural features. Approaches to resolve these problems are a combination of direct studies of forgeability (workability in general), grain movement during hot deformation and mathematical modelling of the metal deformation process.

Planned Activity FY 84/85

- Study the forging behaviour of stainless steels as a function of geometrical configuration, strain rate, temperature and crack initiation.
- Develop a finite element code to model deformation processes and apply the code to study the local strain and grain structure changes in a "simple" metal during hot forming.
- Monitor a contract for a system evaluation of a 500 ton press and prepare a design to upgrade the press.

ROLLING MILL PROCESSING TECHNOLOGY

Project Leader: A.F. Crawley
Telephone: (613) 593-7136

Objective

To develop rolling mill processes for modern high quality steels based on the optimum utilisation of current Canadian facilities and to demonstrate new technological opportunities by designing schedules incorporating thermomechanical processing, interrupted cooling and in-line post rolling control of cooling and by developing a fundamental understanding of the stress-strain characteristics and the metallurgy of the deformation stage.

Background

In order to maintain its market share and competitiveness, the Canadian steel industry must meet demands for steels of high quality and consistency, high strength and toughness, in a range of thickness gauges for pipeline, offshore structures and arctic vessels. For optimum use of current and future rolling facilities a basic understanding of the deformation process and influence of accelerated cooling are essential. Because of the large masses of material and high temperatures involved it is extremely difficult to gain accurate information on the metallurgy and mechanics of roll gap deformation. By judicious experimentation, application of rolling theory and highly sophisticated mathematical techniques such as finite element analysis, insight into the process is attainable. From such information, rolling schedules can be developed and tested on the PMRL rolling mill which is the only such facility in Canada. Based on earlier correlations with industrial mills, schedules can be developed for commercial processing.

Planned Activity FY 84/85

- Monitor contracts to: (1) simulate the hot working of continuously cast HSLA steels (2) commission an on-line accelerated cooling system for the CANMET rolling mill.
- Determine the high temperature flow stresses of Ti-V steels in relation to recrystalization phenomena.
- Develop rolling processes for modern high-strength and tough steels.
- Determine the effects of inhomogeneities in through-thickness deformation and temperature on prediction of mill power and load requirements and microstructural development.
- Test and prepare operating procedures for a on-line accelerated cooling system.

PIPELINES

OIL AND GAS PIPELINES

Project Leader: M.J. Godden
Telephone: (613) 593-7129

Objective

To develop data and supporting theories to optimize linepipe steel chemistry and processing; to improve metallurgical techniques associated with pipeline fabrication and to reduce pipeline failure risk by quantifying the mechanisms of degradation and improving methods of detecting degradation.

Background

Pipeline efficiency is improved by large diameter and high gas pressure, which in turn calls for high strength steels in thick gauges. These steels must also be tough, particularly at the low ambient temperatures characteristic of the Canadian Arctic. One purpose of this project is to apply the outstanding experimental facilities of PMRL to make, process and evaluate experimental controlled rolled HSLA steels of the kind from which pipelines are made to achieve a better understanding of the interrelationships between steel chemistry, processing, microstructure and mechanical properties.

Dents, scrapes and gouges can be inflicted externally during pipeline laying and subsequently, pipelines can be damaged by third parties operating on the pipeline right-of-way. There is a need to assess how much damage pipelines can safely tolerate before fracture initiates.

Recently introduced methods of critical engineering assessment of pipeline defects has highlighted the urgent need for more accurate defect characterization and sizing by ultrasonic and other methods.

Increasingly with the depletion of sweet petroleum deposits, sour wells are being brought on stream increasing the likelihood of pipeline failure from stepwise and sulphide stress cracking. As pipelines age, the external protective wrapping becomes more friable, exposing the pipeline to external corrosion and stress corrosion cracking.

While linepipe steel is available in Grade 483 with good toughness and weldability, the development of matching linepipe fittings has lagged behind. Grade 414 fittings are available but Grade 483 is required.

Planned Activity FY 84/85

- Monitor 5 contracts.
- Investigate accelerated cooling of linepipe steels.
- Optimize linepipe skelp chemistry and processing.
- Study microstructure - property relationships.
- Investigate effect of mechanical damage on fracture of linepipe.
- Investigate stress corrosion of linepipe steel
- Investigate effect of H_2S damage on linepipe.
- Investigate defect recognition and sizing in pipeline welds by UT.
- Evaluate weld consumables for Grade 414 large-diameter linepipe fittings.

OIL COUNTRY TUBULAR GOODS

Project Leader: G.E. Ruddle
Telephone: (613) 593-7136

Objective

To develop and evaluate materials and processing techniques for producing seamless (and ERW) tubing with high collapse strength and resistance to corrosion in deep oil and gas well environments.

Background

Seamless and ERW tubing for oil and gas recovery in drilled wells is a potentially significant domestic and export market for Canadian steel tubular producers. Requirements of rich alloying composition, controlled thermal processing, and high quality control of dimensional, mechanical and corrosion-resistant properties classify the seamless tubing in particular as a premium product.

As shallow and sweet oil and gas wells are depleted, higher quality tubular goods are needed for deeper wells in harsher environments. A competitive position in the casing market requires metallurgical developments in steel alloying composition, and in tube forming and heat-treatment processing, to achieve tubular casing with high collapse strength, good resistance to sulfide stress corrosion failure, and adequate ductility and fracture toughness.

This project will evaluate the sulfide stress corrosion cracking resistance of an Algoma grade 620 (90) steel, and determine the metallurgical steps necessary to develop similar high corrosion resistance in a grade 725(105) steel. Also, the short bar test will be evaluated as a means of ductility and toughness quality control in high strength tubular steels.

Planned Activity FY 84/85

- Develop modified 4130 compositions and post-forming heat treatments to produce tubular steels with increased yield strength and high SSC resistance.
- Evaluate the SCC resistance of modified 4130-type high strength tubular steels.
- Evaluate the short bar test as a means of controlling the ductility and fracture toughness of modified 4130-type high strength tubular steels.
- Monitor a contract for a literature survey on the corrosion resistance of 4130-type oil country tubular steels.

WELDING

EFFECT OF NITROGEN ON WELD NOTCH TOUGHNESS

Project Leader: J.T. McGrath
Telephone: (613) 593-7114

Objective

To determine the effect of nitrogen on the notch toughness of welds prepared in steels for linepipe and offshore structures.

Background

The advancement of BOF steelmaking has led to the development of low-sulphur steels. Inherent with the reduction of sulphur can be the increase in nitrogen content (0.015%).

Both pipe producers (Stelco Inc.) and pipeline owners (NOVA) have identified the potential problem of reduced notch toughness in the HAZ of pipe welds, resulting from the presence of high nitrogen levels.

Planned Activity Fy 84/85

- Prepare nitrogen bearing steels using the PMRL "clean steel" facility.
- Simulate HAZ region in nitrogen bearing steel plate.
- Evaluate HAZ microstructure and notch toughness.

PRESSURE VESSELS

Project Leader: J.T. McGrath
Telephone: (613) 593-7114

Objective

To develop and evaluate fabrication and inspection technologies, to characterize and evaluate properties, and to simulate in-service performance of pressure vessel materials.

To monitor materials performance of vessels in service and develop repair strategies.

Background

The future requirements of the petrochemical industry in terms of processing plants for the treatment of tar sands, heavy oil, coal gasification, etc., project a demand for reactor vessels of increasing size and service capability. If this demand is to be met by Canadian fabricators, the level of technology must be increased to allow them to be competitive with offshore industry, which in many instances, already possess the technological capability for heavy walled vessel fabrication. These large vessels must be fabricated to optimize service performance. In this regard, the petrochemical industry, which will operate the processing plants, must have assurance that the integrity of the vessels will be adequate to function satisfactorily in the service environment.

Planned Activity FY 84/85

- Monitor three contracts.
- Evaluate the factors controlling disbonding between stainless steel overlay and Cr/Mo base metal subject to simulated service exposure.
- Evaluate temper embrittlement of a selection of Cr/Mo weld metals.
- Develop and optimize processes for fabricating heavy wall pressure vessels.
- Predict power requirements for roll forming of heavy sections.
- Design a system for locating and sizing defects in heavy section weldments using ultrasonic tomography.

REPAIR AND RECLAMATION BY WELDING

Project Leader: R.D. McDonald

Telephone: (613) 593-7114

Objective

Conservation of energy, materials and costs in the Canadian mining industry.

Background

Millions of dollars are lost in Canadian industry annually because of worn-out components. These losses are made up of (a) the need to purchase new parts and (b) the "down time" to industry resulting in loss of productivity. Because of rising materials costs and uncertainties in supply of critical alloying elements, more and more attention is being paid to (1) repairing and restoring broken or worn out parts and (2) improving part design and materials selection to reduce total life-cycle costs.

A study of repair and reclamation technology in Canada has shown that the need for such technology is diffuse and in many cases poorly documented. Because of the role that mining plays in the Canadian economy, the initial focus of the project will be on the repair of cast iron components in mining machinery. The project will use the case-study approach to gather data on the uses of cast iron in mining equipment and on repair and down time costs. Based on these data, research work will be carried out to determine optimum procedures for the repair of cast-iron components of mining equipment.

It is expected that as the project progresses other applications will be studied e.g., repair of steel mill rolls, material transportation equipment and agricultural equipment.

Planned Activity FY 84/85

- Monitor a contract to upgrade current weld repair methods and develop new or improved procedures.

THERMAL/MECHANICAL SIMULATION OF METALLURGICAL PROCESSES

Project Leader: J.T. McGrath
Telephone: (613) 593-7114

Objectives

To simulate metallurgical processes such as continuous casting, hot rolling, and welding using the Gleeble simulator.

Background

The improvement of metallurgical processes such as continuous casting, hot working and welding may require costly production trials to develop new operating procedures. The Gleeble 1500 thermal/mechanical simulator, which can simulate the thermal/mechanical operations involved in many of these processes, can be used to determine the effects of changes in process operating parameters.

The information gained from these laboratory based studies can be implemented into full scale production procedures.

At present, 4 cooperative programs with Canadian industry are underway to simulate continuous casting of steel and the heat affected zone region of steel weldments.

Planned Activity FY 84/85

- In collaboration with the Welding Institute of Canada, compare the structure and toughness of the heat affected zones of actual welds with simulated welds in microalloy steels.
- In co-operation with Dr. Ferguson of Duffers Associates, compare CCT data obtained from the MMC dilatometer and the Gleeble 1500.
- Examine the effect of heat input on the structure and toughness of the weld heat affected zone of a range of microalloy steels.
- Simulate the thermal history of various locations of a cast slab and measure the ductility over a range of temperatures for several crack susceptible steels.
- Examine the effect of thermal stresses on cracking susceptibility of a range of steels.

WELDING PROCESS DEVELOPMENT

Project Leader: J.T. McGrath
Telephone: (613) 593-7114

Objective

To develop advanced welding tehcnologies for fabricating of heavy section pressure vessels for energy conversion systems.

Background

The production of large thick-walled steel pressure vessels for energy conversion systems such as upgrading of bitumen and heavy oils, the liquefaction of coal, and gasification and coprocessing of coal and bitumen, requires the development of welding processes and procedures for mill and field fabrication. The welding processes must be able to join pressure vessel steel plate 175 mm to 400 mm thick and produce welds of such quality that they will meet NDE inspection and mechanical property requirements specified by pressure vessel codes.

In the final phase of the external work, full scale demonstration of the welding technology should be made in the form of the manufacture of representative welded sections of pressure vessels.

Planned Activity FY 84/85

- Monitor a contract on narrow gap welding process development.
- Prepare heavy section welds with microstructure and mechanical properties that meet pressure vessel code requirements.
- Establish the relationship between weld process variables and wire feed speed for a given automatic welding process.
- Using ultrasound, study novel methods of detecting, locating and sizing defects in metals.

WELDING MECHANICS

Project Leader: J.T. McGrath
Telephone: (613) 593-7114

Objective

To develop experimental and analytical techniques to determine and predict residual stresses and distortion resulting from the welding of steel structures.

Background

Metal distortion and residual stresses due to welding are present in all welded engineering structures. It is essential that experimental and analytical techniques be developed to assist in predicting residual stresses and distortion.

Controlling distortion is a major cost to welding fabricators and often must be corrected by expensive machining. Knowledge of residual stresses in welded joints is essential in: (a) avoiding weld cracking, particularly in the welding of thick sections and (b) determining the potential service life where failure from stress corrosion, fatigue, and brittle fracture is possible.

Planned Activity FY 84/85

- Evaluate residual stresses in single and multipass welds.
- Monitor a contract to predict the residual stresses in single pass welds by the finite element method.

OTHER

CERTIFICATION OF NDT PERSONNEL

Project Leader: V.L. Caron
Telephone: (613) 593-7106

Objective

To certify NDT Personnel on a national basis in accordance with CGSB standards.

Background

The current strong growth of NDT reflects national concerns for (1) public safety linked with the structural integrity of engineering structures (nuclear plants, pipelines, etc.); (2) product quality; (3) conservation of resources; and (4) improved productivity. Increasingly, contracts specify that products must be approved by certified NDT personnel applying CGSB specifications. The certification of qualified NDT personnel must be impartially controlled according to CGSB standards. In Canada, there is a widespread consensus of opinion that the certification of NDT personnel is a function best performed in the public sector.

The role of certification authority of NDT personnel has for many years been assumed by EMR on a cost recovery basis. An extensive network of regional test centers have been set up throughout Canada at various DND establishments and provincial institutions in order to ensure their accessibility by the public. Examinations are both set and marked by the central authority, EMR, in order that uniformity is maintained.

Planned Activity FY 84/85

- Certify NDT personnel on a national level.
- Continue automation of certification system.

COST RECOVERY AND TECHNOLOGY TRANSFER IN METAL PROCESSING

Project Leader: R. Thomson
Telephone: (613) 593-7075

Objective

To provide analytical, consultative and investigative services on a cost recovery basis to industry, government and other non-profit organizations.

To ensure that technology developed in the Metals Processing sub-activity is transferred to industry and to maintain a continuing record of such transfer for this sub-activity.

Background

The Physical Metallurgy Research Laboratories of CANMET has certain unique facilities and expertise which cannot be easily or profitably duplicated elsewhere in Canada. Other organizations are allowed to draw upon these resources from time to time in emergency situations, on a cost recovery basis.

Planned Activities FY 84/85

- In co-operation with ESCO Ltd. and Syncrude Co. Ltd. produce and test CANCOAT digger teeth.
- Field test and modify software developed by CANMET and Queen's University for the risering of short-freezing range alloys.
- Monitor a contract to investigate the production of heat resistant castings with controlled microstructures.
- Produce two issues of the CANMET Foundry Newsletter.
- Develop microcomputer software for the control of foundry processes and the analysis of processing costs.
- Assess the efficiencies and cost of induction furnaces in iron foundries in Ontario.

COST RECOVERY & TECHNOLOGY TRANSFER IN MATERIALS DEVELOPMENT

Project Leader: D.W.G. White
Telephone: (613) 593-7074

Objective

To provide analytical, consultative and investigative services on a cost recovery basis to industry, government and other non-profit organizations, and to facilitate the commercial exploitation of materials technology being developed in CANMET.

Background

The Physical Metallurgy Research Laboratories of CANMET has certain unique facilities and expertise which cannot readily be duplicated elsewhere in Canada. Other departments, organizations and companies draw on these resources from time to time in emergency situations, on a cost recovery basis.

Planned Activity FY 84/85

- Prepare technical reports to companies and other agencies as required.
- Prepare technology transfer reports.

NDT TECHNOLOGY DEVELOPMENT

Project Leader: V. Caron

Telephone: (613) 593-7106

Objective

To contribute to the development and application of non-destructive testing technology for research and industrial applications.

Background

As metallurgical processing technologies become more refined in the areas of on-line quality control and statistical process control for increased productivity, the reliance on, and requirement for, sensors and non-destructive test procedures becomes more urgent. On-line temperature measurement, product sizing, defect detection and sizing are candidate areas for instrumentation development and characterization using the existing technology base of ultrasonics, eddy current, infra-red measurement systems. In addition, the use of lasers, fibre optics, noise thermometry, computerised defect pattern recognition, are active areas for technical development.

Planned Activity FY 84/85

- Conduct field treals of acoustic emission prototype.
- Evaluate defect-pattern recognition systems.
- Develop and test software for eddy-current prototype.